Precision Assault Navigation System

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LONG-TERM GOALS

Future operational scenarios and weapons systems require precise navigation for missions such as Operational Maneuver From the Sea (OMFTS), particularly when the operation occurs in a littoral area containing the threat of mines. The long-term goals of this study are to fully develop the concepts for a precision navigation system. The intent is to demonstrate the system in a future ATD and to eventually deploy the Precision Assault Navigation System (PANS) as a rapidly deployable, highly accurate (2 m Circular Error Probable (CEP), non-GPS dependent navigation system with GPS interoperability.

OBJECTIVES

During the PANS Phase I BAA (Reference [1]), an analysis was conducted to determine the performance of a navigation system with several beacons on the shore in stationary positions and several mounted on buoys in the water. Performance parameters considered included the ranging accuracy, path loss, and the CEP. Phase II of the study has several objectives listed below. The high accuracy system would be integrated into the KSQ-1 amphibious assault command and control system.

NAVIGATION ANALYSIS

The final configuration of the system must be deployable without placing beacons on the beach and possess a self-survey mode. During operation, the system must support low flying aircraft, Landing Craft Air Cushion (LCAC) vehicles, and fire control for Explosive Neutralization (EN) systems. One specific objective of phase II is to analyze performance at altitudes up to 1000 feet, with all beacons placed in the water and investigate methods of supporting the LCAC Fire Control Solution for EN systems.

EXPERIMENT TASK

The initial PANS concept was a system based on the Gulf Range Drone Control System (GRDCUS) (see reference [2]). Although Phase I recommended changes to the waveform to enhance anti-jam performance, the manner in which the ranging data is used to compute a navigation solution has not

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changed. Also, the frequency range is likely to remain in the L band as described in Phase I. Therefore, it is critical to validate the analytical propagation and multi-path results of Phase I through experimentation. Use of the GRDCUS system provides an economical means to do so. Under an agreement with the Air Force, measurements will be taken from a van parked on the beach to beacons located in the water on a boat. The objective is to validate multi-path signal fade and ranging accuracy.

APPROACH

The navigation analysis will be performed by augmenting the MATLAB (a software analytical tool) based covariance analysis employed during Phase I and described in the Phase I final Report (Ref [1]). The error equations will be documented in the Phase II final report at completion of the study.

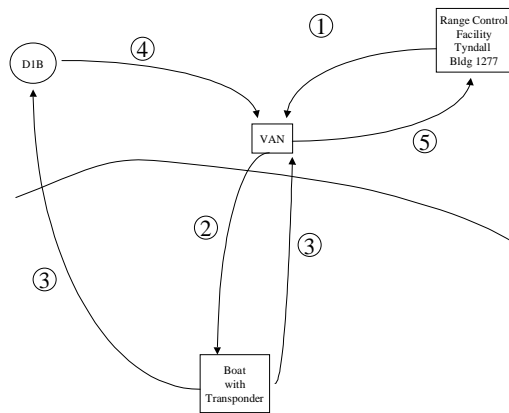The experimental phase of the program is conducted in two phases. The experimental setup is shown in Figure 1.

Figure 1. Experimental Setup

The van indicated in Figure 1 is owned by the 46th Test Wing at Eglin and is operated by a subcontractor (Marconi). The van will be parked at CSS Beach site #2, which has line of sight to the Range Control Facility at Tyndall. The experiment will be conducted over a weekend to avoid conflicts with other users of the range during the week. Two different test scenarios are anticipated:

Test 1. Verify link margin prediction

The purpose of this experiment is to verify the link margin as predicted in the PANS Phase I study. In this experiment the Range Control Facility is not required. The van transmits a signal (path 2) to the boat. If the boat hears the signal it responds (path 3). An operator in the van records the attenuation, the range as determined by the time of arrival (TOA) of the signal, and the GPS time. If no response is heard by the van, the operator records the fact that no response was provided at that particular time. Ideally we would also record the GPS position of the boat vs. GPS time if those measurements can easily be mechanized. It is desirable to automate this recording function as much as possible to reduce errors in data collection.

Test 2. Verify Signal Ranging Accuracy

In this experiment the objective is to measure the ranging accuracy of the TOA signal from the van to verify the predictions in PANS Phase I. Note these predictions are based on the frequency of the signal, the shape of the correlator and the reflection coefficient and phase shift off the water. In theory, future changes to the waveform would not affect the results provided the shape of the correlator and polarization (which determines reflection properties) remained the same.

In this experiment the Range Control Facility (RCF) is required to provide differential GPS position of the boat. This is required for a truth reference. The van is parked at the same location as experiment 1, which provides line of sight to the Range Control Facility. The ranging measurement is initiated by a broadcast from the RCF to the van. The van then transmits to boat. In experiment 2 the attenuation (from experiment 1) is removed from the van transmission path. The boat responds and is heard by the van and tower D1B. Tower D1B then responds to the van and the van responds back to the Range Control Facility. An output file is then available from the Range Control Facility that indicates GPS Time, Differential GPS position, and Range based on TOA. Other data may be included if available, such as the raw TOA information and GPS pseudorange information. Using these data, ranging accuracy can be verified to the level of accuracy provided by differential GPS. If the raw pseudorange information can be made available, it is possible the differential accuracy can be enhanced by application of corrected ephemeris data several days after the experiment to obtain better accuracy.

WORK COMPLETED

Phase II of the PANS study is about half-complete at the time of this publication. An analysis of altitude and placing all beacons in the water has been investigated and is discussed in this report. The experimental phase of the study will be conducted in early November 1998.

RESULTS

Effect of Altitude on Navigation Performance

Our MATLAB simulation from Phase I has been modified to account for the effect of altitude on navigation accuracy. Figure 2 shows the beacon locations and test location under study. This test location was chosen because it has one of the highest GDOPs in the navigation grid. We assume the beacons on land are operating with no watch circle error, and the beacons in the water have a 3-meter 1-σ error. We ran the analysis at the test location in the grid at altitudes of sea level, 25, 50, 100, 250, 500, and 1000 meters. The results are:

Altitude (meters)	CEP (meters)
Sea Level	2.1
25	2.3
50	2.4
100	2.5
250	2.6
500	2.6
1000	2.6

According to these findings, there does not appear to be any significant degradation due to altitude up to 1000 m.

beacon 1
(0 nm, 20 ft)   Land   beacon 2
(2.5 nm, 20 ft)   beacon 3
(5 nm, 20 ft) ●

x

Water

Key:

● - beacon location

x - test location

beacon 4
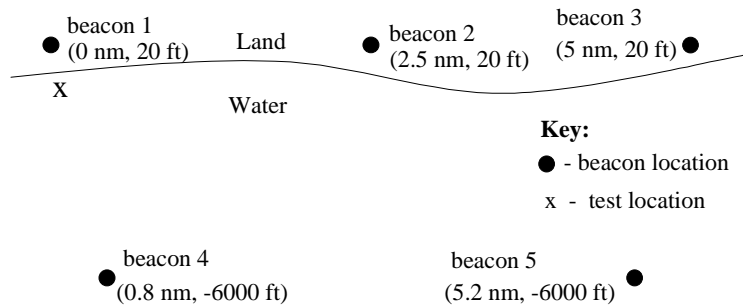(0.8 nm, -6000 ft)   beacon 5
(5.2 nm, -6000 ft)

Figure 2. Beacon and Test Locations

System Robustness with Respect to loss of a buoy

Using the same watch circle assumptions and test location as above, we evaluated the effect of losing a beacon on the navigation accuracy at both sea level and 1000 meter altitude. The results are:

Missing Beacon #	CEP (m) at 1000 m	CEP (m) at SL
1	4.8	4.6
2	2.8	2.2
3	2.7	2.2
4	4.6	4.2
5	2.7	2.2
None	2.6	2.1

As indicated by these results, the loss of a beacon can have a significant effect on navigation accuracy. The effect varies with which beacon is eliminated and the location in the grid where the accuracy is evaluated. For the test location selected, beacons 1 and 4 were the most critical. If the test location were to the far right of the figure instead of the far left, beacons 3 and 5 would be the most critical.

Performance of PANS with No Land Beacons

We evaluated the performance of the system when all beacons are placed in the water on buoys. The buoys are arranged in the same pattern as previously indicated, except the beacons formerly on the beach are now placed in the water just beyond the surf zone. To estimate the buoy watch circle, we assumed that the water depth 2000 feet off shore is about 10 ft. The resulting navigation accuracy is reported for a range of watch circle errors.

Watch Circle Error (feet)	CEP (meters)
5	2.6
10	3.6
12	4.0
15	4.8

IMPACT/APPLICATIONS

The analysis indicates that deployment of the beacons off shore will increase navigation CEP as a function of watch circle error of the beacons formerly on the beach. The increased error in navigation performance may be a good trade off with the advantages of full deployment of the system in the water.

TRANSITIONS

The PANS Phase II BAA (N61331-98-C-0032) will complete this year with a plan to further develop this technology under an Advanced Technology Demonstration (ATD) in order to reach a Milestone I/II decision by FY03. Two advanced technology proposals have been submitted, one to NAVSEA and one to NAVAIR, to recommend an ATD follow-on activity to the PANS study. A decision has not yet been reached on these ATD's. The concept for the ATD's is to demonstrate new technology developed by the PANS study and to combine it with technology from Navigation Warfare. The concepts for deployment and specialized techniques for developing the navigation solution for PANS are unique and differ from pure GPS. However, these concepts could still be employed with the GPS waveform to exploit anti-jam characteristics developed by Navigation Warfare. High-risk technologies include the adaptation of GPS pseudo-lites to operate in the surf zone and digital beam forming antenna and processors for use in GPS based weapons systems and helicopters. The findings from the PANS Phase I and II BAA's directly support technology required for these ATD's.

RELATED PROJECTS

Related projects include:

1. Joint Countermeasures ATD
2. Explosive Neutralization ATD
3. EX 9 Mod 0 Mine Clearance System, SABRE
4. EX 10 Mod 0 Mine Clearance System, DET
5. Landing Craft Air Cushion Service Life Extension Program (SLEP)
6. MK 7 Mod 0 Beacon, Navigation Breech Lane
7. AN/KSQ-1 Amphibious Assault Direction System

REFERENCES

[1] Precision Assault Navigation System, Final Report, August 1997.

[2] IBM Technical Directions, Vol. 9, No. 1, 1983.